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Investigating the surface distribution of N_2, CH_4 and CO ices on Triton with a volatile transport model

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1. Introduction

The flyby of Pluto by New Horizons in July 2015 highlighted the extraordinary complexity of the main icy bodies of the Kuiper Belt. The largest satellite of Neptune, Triton, is thought to belong to this family and is often referred as the twin sister of Pluto, as both bodies share similar sizes, densities, atmospheric composition, pressures and temperatures, types of ices (water ice, and volatile nitrogen, methane, CO ices) and probably comparable climate and geology (in particular that related to the flow of nitrogen ice and the condensation-sublimation cycles). However, Triton developed a different (and maybe even more complex) personality than its sister, as attested for instance by the observation of active geysers by Voyager 2 during the 1989 flyby or by the much higher surface albedo (suggestive of extensive resurfacing). In addition to the Voyager data, several ground-based observations of Triton's as well as modeling effort have been performed, leading to different scenarios for the surface distribution of the volatile and non-volatile ices [1][2][3].

Here we present numerical simulations designed to model the evolution of Triton's volatiles over millions of years on the basis of straightforward universal physical equations.

The model used is derived from the Pluto volatile transport model [4], in which the characteristics of Triton's orbit have been used. Our main goal is to investigate where the volatile ices tend to accumulate on Triton, and compare our results with the available observation in order to paint a global portrait of Triton's face. In particular, we investigate if a perennial northern polar cap of nitrogen ice can form.

2. The volatile transport model

1.1 A common model for Pluto and Triton

The model is derived from the Pluto volatile transport model, and takes into account the volatile cycles of N_2, CH_4 and CO [4], a glacial flow scheme for N_2 ice [5] and the seasonal variation of the subsolar point specific to Triton. This variation is complex and we used the solution from [6], which we extrapolated to simulate Triton over the last millions of Earth years.

As in the Pluto model, we consider that Triton's atmosphere is very thin and almost transparent so that it has a negligible influence on the surface thermal balance. We parametrize the atmospheric transport using a characteristic time for the redistribution of the surface pressure and trace species, based on reference GCM simulation.

1.2 Sensitivity parameters

As it is the case for Pluto, the modeled ice cycles on Triton are sensitive to the assumed surface and subsurface properties, which are poorly constrained for now. The key parameters of the model are:

- The ices albedo and emissivity, which can evolve depending on the age or thickness of the deposits and on the sublimation or condensation flux.
- The thermal inertia for each ice, and the geothermal flux.
- The reservoir of volatile ices, which is thought to be less than on Pluto due to the volatile escape following the capture process by Neptune and the subsequent tidal interactions and heating of the surface and escape [7].
- The topography, which likely impacts the volatile ice distribution as it is the case on Pluto.

3. Preliminary results

We investigate the presence and stability over time of a northern polar cap of nitrogen, assuming that there is a perennial cap at the south pole. We show a brief example of simulation.

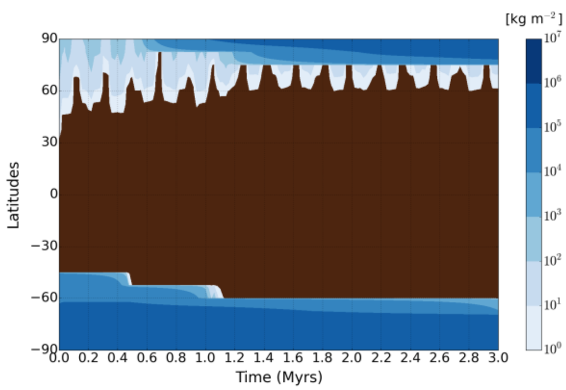
3.1 Initial state of the simulation

We place a 100 m N_2 ice deposit below 50°S. N_2 ice has an albedo of 0.7 in the model, an emissivity of 0.8 and a thermal inertia of 800 SI. The rest of the surface is volatile-free and has a very dark albedo of 0.1, coupled to a high soil thermal inertia of 1000 SI. The soil temperatures are initialized at 50K.

3.2 Volatile evolution

As shown by Figure 1, we obtain a slight retreat of the initial south polar cap and the formation of a perennial polar cap above 75°N. N_2 frosts form between 60°N-75°N.

Figure 1: Simulated evolution of the amount of N_2 ice over 3 million years. The dark brown color indicates the volatile-free regions.



3.3 Discussion

In most of our simulation performed, a perennial polar cap of nitrogen forms in the northern hemisphere. It may not form only if we assume a very high thermal inertia (>2000 SI) coupled to a low bedrock surface albedo (<0.1) and a not too large reservoir for the south polar cap (<2km). However, Triton's surface is very bright and such a low albedo does not seem realistic. Consequently, our results support the presence of a north polar cap of nitrogen ice.

We plan to further explore the impact of each key parameter on the results. In particular, an asymmetry of topography or geothermal flux may favor one cap over the other. In addition, we will compare the model results with the available observations of Triton. In particular, we aim to reconcile a consistent pressure cycle and methane and CO atmospheric mixing ratio with an extension of the south polar cap in accordance with Voyager 2's observations.

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